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## RELATION OF SPECIFIC GRAVITY TO THE QUALITY OF DRIED PRUNES


P. F. NICHOLS[1] and H. M. REED[2]


Aside from the general provisions of the Federal Food and Drugs Act of 1906, which deal with sanitation, adulteration, and the misbranding of foodstuffs, there are no legal standards of quality for dried prunes. The standards for quality, apart from size, used in the industry also are confusing and involved, and the specifications used are expressed in very vague terms. During the evolution of the industry, which is centered in several widely separated districts of the state, geographical names have come to be associated with, and even to represent, grades of quality. Thus there are found in trade usage such terms as Santa Clara, Northern California, San Joaquin, California, Northern Outside, Colusa, Napa, Sonoma, and Suisun. Of these, the first carries the most prestige and is applied only to fruit of the best quality, while several of the other terms are practically synonymous. The usefulness of these names as quality designations has been impaired somewhat by the recent decision of the Federal Food and Drugs authorities that geographical terms may be used in domestic trade to refer only to products of the localities named. Such general terms as Extra Fancy, Fancy, Extra Choice, Choice, and Standard, which are commonly used to designate grades of quality in other California fruit products, are not generally applied to dried prunes. The specifications for various prune grades use such indefinite terms as "a great predominance of clear amber meat,"


[1] Associate in Fruit Products.

[2] Graduate Assistant in Fruit Products.

"containing any material percentage of scabby, slabby, fermented or split specimens," or "fruit of a coarser, more fibrous and porous texture."(1) [3] The grading is done by the visual inspection of individuals, who base their segregations upon the general external appearance of the fruit and the condition of the flesh as shown by cutting a few specimens. Finally, the system is complicated by being of the flexible type, varying from year to year. This is for the purpose of maintaining approximately the same proportion of the crop in each grade each year regardless of the seasonal variations in crop size and condition.

In contrast to the more general aspects of quality, size is usually expressed very specifically as the 'count' or number of fruits to the pound. Usually fruit is sized or size-graded in count ranges of 10, as 20–30, 30–40, and so on. Even in this matter, trade practice is not entirely uniform, since some packers separate the fruit into only three size groups—large, medium, and small—in each of which the range of size is 20 'points' or more.

From what has been said so far, it should be clear that the present basis of quality classification contains a large element of personal and individual judgment. In connection with some investigations of the effects of different harvesting and drying practices upon the quality of dried prunes, it became necessary to have more exact means of determining and comparing the quality of different lots. The tests to be described here were developed to meet this need and also, if they appeared satisfactory for the purpose, to form the basis for improved commercial grading methods. With respect to this second object of the work, it may be said that it is not our purpose to alter the existing commercial grades but rather to provide grading methods more reliable than those now in use.

Among the characteristics of quality in dried prunes, the color and texture of the flesh are of great importance. In fruit of best quality, the color of the flesh is amber, or lighter, and the flesh is solid in texture (fig. 1). Since good flesh color is commonly associated with solid texture in dried prunes, and vice versa, and since texture in different prunes varies all the way from solid to the extreme of porosity characteristic of 'bloaters' in which are one or more large air pockets, measuring the specific gravity of the fruit directly or indirectly was believed to be a promising method of measuring both color and texture of the flesh.

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[3] Superscript numbers in parentheses refer to selected references at the end of this publication.

## MATERIAL STUDIED

Since prunes of the French (Agen) variety constitute about 90 per cent of the crop in California, only this variety was studied intensively. It is believed that tests found to be of value for this variety will probably be of equal service with other varieties even though the characteristics and grade requirements may not be identical. The material used in this study was obtained from packing houses in the four principal prune-growing districts of the state.


Fig. 1. Flesh texture of prunes: *a*, solid; *b*, bloaters.

The districts were designated by letters as follows: A, the Sacramento Valley; B, the Napa-Sonoma district; C, the Santa Clara Valley; and D, the San Joaquin Valley. Districts A and D are those commonly known in the trade as the "outside districts," while B and C are known as the "inside districts" or "three districts."

From what has been stated in the introduction regarding the use of geographical names as designations of quality, it will be seen that getting prunes from each district representing each of the quality grades recognized in the industry was impossible, and it was not feasible to proceed as had been done in the raisin standardization study to which reference has been made.[2] In the raisin study, samples were obtained from each of the many receiving stations involved, and from nearly all plants samples were secured that represented each of the regular grades, namely Extra Standard, Standard, Sub-Standard, and Inferior. The experimental tests were

then applied to all samples and the results were studied, using as a group all samples placed in a single grade by visual inspection, regardless of the district from which they were secured. In the prune quality study, on the contrary, when the samples for examination were secured, the great bulk of the fruit at each packing house had been placed in the single grade characteristic of that district. Most of the samples from each district therefore represented only a single grade. Fruit in this grade, which was the first or best grade in each district, did not, however, necessarily correspond in quality to fruit in the first grade of any other district. For these reasons the samples when tested were grouped for study according to district rather than quality grade.

Two kinds of samples were studied in 1928 and 1929, namely bin samples and growers' samples. Bin samples were composite samples taken from the storage bins at packing houses. Wherever possible such samples were obtained from a trench dug from top to bottom in a bin full of fruit, after it was opened from the side. Thus the fruit in the bin samples had been graded for size and represented in each case many or all of the individual growers' lots of which the bin load was composed.

Each grower's sample, on the other hand, was from a single delivery of a grower and was 'orchard run,' i.e., not size-graded.

In 1930 most of the samples were taken from individual growers' lots before size grading. Only a few composite, size-graded samples were taken from bins, and all samples from each district were grouped together for statistical study.

## EXPERIMENTAL METHODS

Methods of judging or measuring size, skin condition and moisture content will be presented in another paper. The present discussion is limited to the studies of specific gravity and weight per volume, which were found to measure directly the texture, and indirectly, the color, of the flesh.

*Specific Gravity.*—The presence of air pockets of considerable number or size obviously affects the relation between the size and the weight of the prunes. Two physical tests are directly affected by this condition, that of determining specific gravity and of weight per volume. Specific gravity may be determined by weighing an object in air and observing its decrease in weight when suspended in water or some other liquid of which the specific gravity is known.

Because of the great surface tension of water, which tends to catch bubbles of air on the irregular surface of prunes, a mixture of xylene and carbon tetrachloride was found to be a more suitable liquid for use in determining specific gravity. Such a liquid has several advantages. The liquid does not dissolve fruit sugars that would change its specific gravity. The presence of carbon tetrachloride reduces the inflammability of the xylene. The difference in specific gravity of the two liquids permits ready adjustment of the specific gravity of the mixture. On account of its low surface tension it readily wets all parts of the fruit, thus releasing any bubbles of air caught in the wrinkles. The specific gravity of the prunes was, therefore, determined by weighing them in air and again in the xylene mixture.

Individual prunes were studied by this method while suspended by a fine wire. These preliminary tests with individual prunes showed a close relation between specific gravity and internal condition. In the later work one-pound samples were used that, when submerged, were weighed in a wire basket. The equipment required for these tests included:

Balance, capacity 1,000 grams and sensitive to 0.1 gram, provided with a hook under one pan. Pans approximately 6 inches in diameter.
Aluminum pan, 1 liter capacity.
Wire basket, approximately 5 inches in diameter, and 5 inches tall.
Set of weights, 200 grams to 0.1 gram.
Cylindrical can approximately 7 inches in diameter and 10 inches in height. (Preferably fitted with a friction-top lid.)
Commercial xylene.
Commercial carbon tetrachloride.
Specific gravity hydrometer; scale, 1.000 to 0.800 by divisions of 0.005.

The specific gravity of the xylene is adjusted to exactly 0.900 by cautious additions of small amounts of carbon tetrachloride, followed by thorough stirring and testing with the hydrometer. The specific gravity of this mixture changes by 0.001 for each Centigrade degree change in temperature.

The balance is supported above a stand at sufficient height to permit the wire basket, hung by a piece of fine wire from the hook below one of the pans, to be completely submerged in the can filled to within 2 inches of the top with xylene. The level of the xylene should come part way up the supporting wire when no prunes are

in the basket. With the basket thus submerged, and the aluminum dish upon the pan above, the balance is brought to equilibrium by a tare weight on the other pan. (A small can of shot is convenient for the purpose.)

A one-pound sample of prunes is now placed in the aluminum dish and weighed to the nearest gram. The prunes are next transferred to the basket, the aluminum dish replaced on the pan, and the weight again taken to the nearest gram.

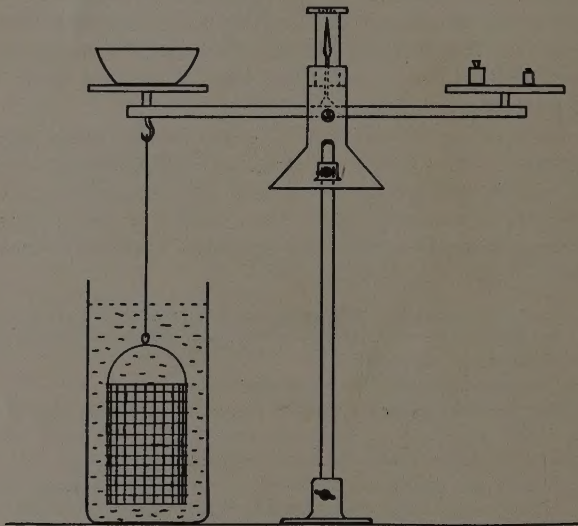

Fig. 2. Diagram of apparatus for specific gravity test.

From the weight of the prunes in air and the loss of weight in xylene (the difference between the two weights observed) the specific gravity may now be calculated by the following formula:

$$\text{Specific gravity of prunes} = \frac{\text{Weight in air} \times \text{specific gravity of xylene}}{\text{Loss of weight in xylene}}$$

The calculating may be omitted and the determination simplified by use of a direct-reading chart (fig. 3).

The specific gravity of the xylene mixture should be checked at least twice a day, and corrected if necessary.

After the determination, the prunes may be spread out in a thin layer in a well ventilated place away from open flames. After one to two days, the xylene will have evaporated completely and the prunes

will show no effect from the immersion. If the fruit is placed over a steam radiator or in a dehydrater the xylene will evaporate in a few minutes.

*Weight per Volume.*—Weight per volume or W/V value is determined by weighing a constant volume of the fruit in a standard container filled in a uniform manner. In the studies made during the first two years the tests were made by filling a 2-quart can with the fruit and mechanically shaking the can at a uniform rate as it

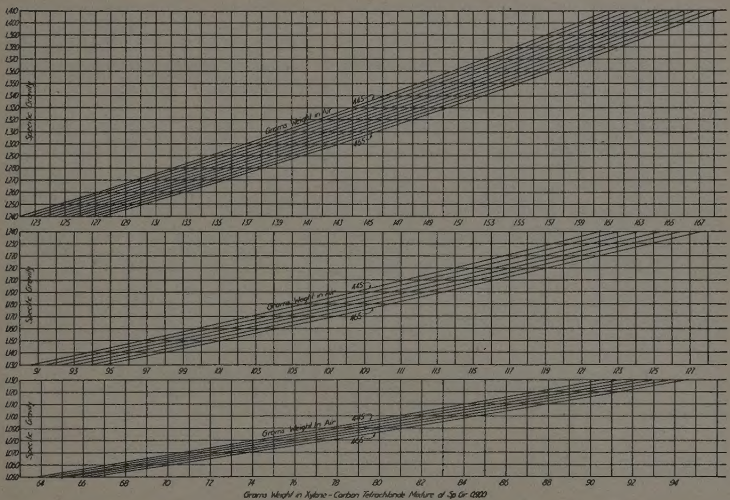


Fig. 3.—Specific gravity from weights in air and in a xylene-carbon tetrachloride mixture having a specific gravity of 0.900. To find the specific gravity (1) find on the proper base line the weight of the samples submerged in the liquid, (2) follow up the vertical line from this point to its intersection with the sloping line corresponding to the weight of the sample in air, (3) from this point of intersection proceed horizontally to the left to the scale from which the specific gravity may be estimated. Note that in the lower two portions of the chart the sloping lines representing the even numbers of grams weight in air have been omitted to avoid crowding of the lines, and the proper points of intersection must therefore be estimated.

was being filled. In 1930 a larger machine was constructed and equipped with a 5-gallon can (figs. 4 and 5) and a large number of samples were tested by both machines in order to determine the relation between the results obtained by them. This permitted the results obtained in all three years of the study to be reported on the same basis, namely, as gross weight of the 5-gallon can and contents in pounds and ounces. This is referred to as the "W/V value."

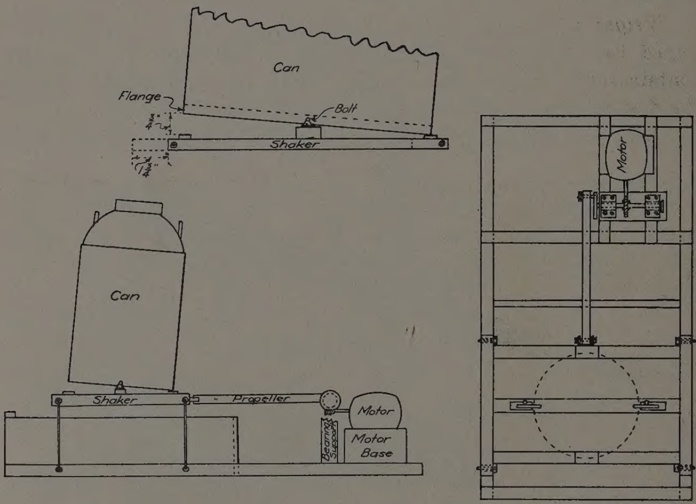


Fig. 4. Diagram of apparatus for weight per volume test.

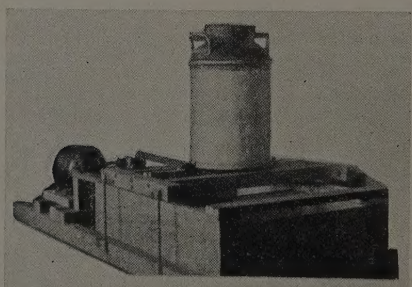

Fig. 5. Apparatus for determining weight per volume.

The essential parts of the 1930 apparatus are a standard round-shouldered 5-gallon milk can and shaker platform.

The flare of the can is cut off smooth at the top of the vertical neck. A ⅜-inch hole is drilled at each of two opposite points in the vertical flange at the bottom of the can. The empty can, with the flared top cut off and without lid, weighs 11 pounds 4 ounces. Filled with water at 54° F, it weighs 54 pounds 8 ounces and thus has a capacity of 43 pounds 4 ounces of water at this temperature, equivalent to 5.07 gallons or 1,171 cubic inches.

The shaker platform has a throw of 1¾ inches and moves at the rate of 88 round-trip cycles per minute. It has a central cross member on which are installed two round sliding door-bolts $5/16$ inch in diameter so located as to slip into the holes in the bottom flange of the can and hold the can in position, acting as bearings for rocking the can during filling and subsequent shaking. The central cross member bearing the bolts is raised so that when the can is bolted in position and held level, the bottom of the can is ⅜ inch above the level of the metal strike plates, allowing the front and back edges of the bottom of the can to move up and down a total vertical distance of ¾ inch during rocking.

The unit is driven by a 110-volt motor of ¼ horsepower running at 1760 r.p.m. A worm on the motor shaft drives a gear on the shaft that drives the shaker, giving a speed reduction of 20 to 1. The drive rod to the shaker is run by a disk at the end of the shaft driven by the motor with a pin ⅞ inch off center.

The shaker platform is supported above the base by four shallow, wide U-bolts $5/16$ inch in diameter, two on each side. Brass bushings in the shaker platform and base provide bearing surface. This supports the shaker platform with the top approximately 12 inches above the floor. Under this platform, the walls of the base are built up, and boxes may be placed under the platform to catch the overflow of prunes.

The feeding of fruit to the can is so regulated as to fill the can, with shaker in operation, in 60 seconds and the shaking is then continued for an additional 60 seconds, meanwhile keeping the can full. If desired, an automatic time switch may be used for stopping the motor at the end of two minutes. After the motor is stopped, the can is heaped with prunes, leveled off by dragging a stick slowly and firmly across the neck of the can, and the can and contents are weighed upon scales reading in pounds and ounces.

## PRESENTATION OF DATA

The data from different examinations will be discussed separately, but are in most cases tabulated together.

*Effect of Size on Specific Gravity and Weight per Volume.*—The results of the tests upon all bin samples of the 1928 crop were studied to determine whether there was association between size and specific gravity. Since these samples had previously been mechanically graded for size, all fruits in each sample were reasonably uniform in this respect. The samples were arranged in size-groups without regard to origin or quality, and the average size, specific gravity, and weight per volume for each group was calculated. The results are shown graphically in figure 6. Judged by these results, variations in size

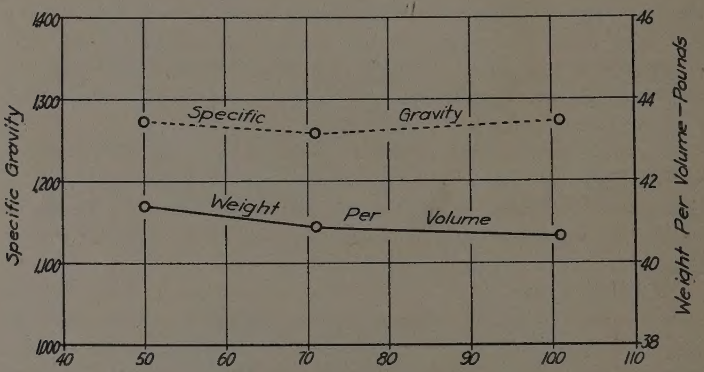


Fig. 6. Relation between size of prunes and their specific gravity and weight per volume.

alone appeared to have no consistent or important effect upon specific gravity or weight per volume. However, since the distribution of variations in quality may not have been the same in each group, the results of this study are not conclusive. A more exact estimation of the direct or indirect influence of size upon specific gravity was gained by a study of individual prunes.

*Effect of Pit on Specific Gravity of Prunes.*—The proportion of pit in French prunes was found to decrease as the weight or size of the fruits increased. Therefore, the influence of the proportion of pit on the specific gravity of the fruit decreased as the size increased. The

nature and extent of this influence was studied by examination of 25 prunes chosen to represent a wide range in size and in quality. The specific gravity of each whole prune was determined. The pit was removed, and the texture of the flesh was noted. The pits were carefully scraped and the proportion of pit was found. The specific gravity of each pit was also determined. From these data the specific gravity of the flesh alone was also calculated. The results are given in table 1.

TABLE 1

SPECIFIC GRAVITY AND QUALITY IN INDIVIDUAL PRUNES

| Prune No. | Flesh texture | Flesh color | Count per pound | Pit, per cent | Specific gravity | | |
|---|---|---|---|---|---|---|---|
| | | | | | Whole prune | Pit | Flesh |
| 1 | Solid | Medium amber | 38 | 9.3 | 1.365 | 1.052 | 1.408 |
| 2 | Solid | Medium amber | 40 | 7.8 | 1.388 | 1.091 | 1.420 |
| 3 | Medium air pockets; slightly spongy | Dark amber | 38 | 7.7 | 1.355 | 1.065 | 1.385 |
| 4 | Air pockets | Medium amber | 47 | 10.4 | 1.360 | 1.085 | 1.401 |
| 5 | Large air pockets | Dark brown | 52 | 12.4 | 1.359 | 1.127 | 1.399 |
| 6 | Solid | Amber | 56 | 12.8 | 1.348 | 1.127 | 1.384 |
| 7 | Solid | Amber | 94 | 13.8 | 1.357 | 1.138 | 1.395 |
| 8 | Solid | Brown | 71 | 13.6 | 1.327 | 1.051 | 1.379 |
| 9 | Solid | Amber | 56 | 12.5 | 1.318 | 1.080 | 1.364 |
| 10 | Solid | Amber | 58 | 14.9 | 1.345 | 1.102 | 1.400 |
| 11 | Solid | Amber | 51 | 19.9 | 1.335 | 1.089 | 1.370 |
| 12 | Solid | Brown | 68 | 12.9 | 1.384 | 1.140 | 1.424 |
| 13 | Solid | Brown | 71 | 17.4 | 1.331 | 1.052 | 1.405 |
| 14 | Solid | Dark amber | 99 | 16.6 | 1.309 | 1.082 | 1.364 |
| 15 | Solid | Dark amber | 57 | 12.4 | 1.356 | 1.081 | 1.439 |
| 16 | Solid | Dark brown | 90 | 11.3 | 1.352 | 0.864 | 1.459 |
| 17 | Solid | Amber | 71 | 15.8 | 1.275 | 1.152 | 1.300 |
| 18 | Solid | Dark amber | 80 | 12.5 | 1.350 | 1.100 | 1.395 |
| 19 | Bloater | Dark brown | 36 | 8.6 | 0.962 | 1.070 | 0.953 |
| 20 | Bloater | Dark brown | 41 | 8.9 | 0.996 | 1.054 | 0.991 |
| 21 | Large air pockets | Dark brown | 27 | 7.8 | 1.295 | 1.055 | 1.320 |
| 22 | Bloater | Amber | 69 | 13.3 | 1.223 | 1.109 | 1.242 |
| 23 | Bloater; a "mummy" | Brown | 187 | 28.8 | 1.131 | 0.932 | 1.235 |
| 24 | Bloater | Dark brown | 116 | 18.6 | 1.084 | 1.121 | 1.075 |
| 25 | Injured by insects | Dark brown | 188 | 32.2 | 1.206 | 1.052 | 1.285 |

It will be noted that (1) the specific gravity of the pit is remarkably constant, regardless of the size or condition of the prune; that (2) the specific gravity of the whole prune and of the flesh tends to be high in the case of the solid prunes, and to be distinctly lower in the case of the bloaters and prunes with large air pockets; and that, (3) generally, dark-colored flesh is not found in solid prunes. While several exceptions to these generalizations appear, some of them have possible explanations in the light of the other characteristics shown.

The average specific gravity of the pits was 1.072 while that of the whole prunes was 1.285. The range of specific gravity of the whole prunes was from 0.962 to 1.388, a difference of 0.426. The range of specific gravity of all the pits was from 0.864 to 1.152, a difference of 0.288. Excluding prunes No. 16 and No. 23, in which the values were exceptionally low, the specific gravity of the pits ranged only from 1.051 to 1.152, a difference of 0.101, or about one-fourth the fluctuation found in the whole prunes. The range of specific gravity of the flesh of all the prunes was from 0.953 to 1.459, a difference of 0.506, or about five times as great as the usual fluctuation of the values for the pits.

The average effect of the pit was to reduce the specific gravity of the whole prunes by 0.045. The average deviation from this reduction was 0.020, so that the change was usually within the limits of 0.025 and 0.065. The effect of the pit on the specific gravity of the whole fruit is, of course, determined by the proportion of pit, the specific gravity of the flesh, and that of the pit. In large prunes, since the proportion of pit is smaller, the effect on the specific gravity is less than in small prunes. Thus in large prunes, counting 40 or fewer to the pound, the average change was 0.028; in prunes counting more than 40 but under 81 to the pound, the average change was 0.042; while in prunes counting 81 or over, the average change was 0.065. Also since the specific gravity of the pit is usually lower than that of the flesh, the numerical effect of the pit upon the specific gravity is smaller when the specific gravity of the flesh is low. As a rule, the irregularity of the specific gravity of the whole fruits resulting from the influence of the pits was within 0.020, and since this is only 5 per cent of the range for the whole fruit, it was believed that the error introduced was not significant and could be disregarded.

*Sugar Content.*—Chemical examination of the samples was limited to the determination of sugar content in the bin samples of the 1928 crop. The determinations were made not on the samples as a whole but upon solid-fleshed fruits only, those with air pockets being discarded in preparation for analysis because of their probable partial decomposition. The results are summarized in table 2.

These variations in sugar content are similar in character to those obtained by Hiltner and Hatherell[4] and by Cruess and Gale[3] on other material.

An association between sugar content and specific gravity has been observed by Wiegand and Bullis[7] in a report published since this work was begun. That there is a general association between

sugar content and both specific gravity and weight per volume is shown in table 2. The specific gravity and W/V value tend to be high when the sugar content is high. However, the decomposition of but a very slight amount of sugar might produce gas pockets, bad flesh texture, and color, and markedly affect the specific gravity and the W/V value without appreciably affecting the percentage of sugar present. Therefore, the sugar content does not offer a satisfactory criterion of quality in prunes.

TABLE 2

SPECIFIC GRAVITY, WEIGHT PER VOLUME, AND PERCENTAGE OF SUGAR OF BIN SAMPLES OF THE 1928 CROP

| District | Number of samples | | Specific gravity | Weight per volume | | Total sugar |
|---|---|---|---|---|---|---|
| | | | | *pounds* | *ounces* | *per cent* |
| A | 17 | Average | 1.231 | 40 | 5 | 41.3* |
| | | Maximum | 1.301 | 42 | 3 | 49.2 |
| | | Minimum | 1.174 | 38 | 10 | 37.9 |
| B | 11 | Average | 1.329 | 41 | 15 | 48.2† |
| | | Maximum | 1.429 | 42 | 13 | 52.4 |
| | | Minimum | 1.270 | 40 | 12 | 44.3 |
| C | 12 | Average | 1.312 | 42 | 0 | 53.6 |
| | | Maximum | 1.352 | 41 | 11 | 56.1 |
| | | Minimum | 1.276 | 39 | 15 | 49.7 |
| D | 11 | Average | 1.215 | 39 | 6 | 40.0‡ |
| | | Maximum | 1.275 | 41 | 0 | 42.7 |
| | | Minimum | 1.138 | 37 | 6 | 38.1 |
| All districts | 51 | Average | 1.268 | 40 | 14 | 45.5 |
| | | Maximum | 1.429 | 43 | 8 | 56.1 |
| | | Minimum | 1.138 | 37 | 6 | 37.9 |

* 16 samples. † 8 samples. ‡ 10 samples.

*Note:* Total sugar is reported as invert, and is calculated to a basis of 20 per cent moisture in the flesh of the fruit. Determinations made by B. L. Hatherell and C. D. Fisher, Dried Fruit Association of California.

*Observations on Specific Gravity.*—The maximum and minimum values for specific gravity found for all three seasons were 1.429 and 1.122, a range of 0.307. For individual fruits, the specific gravity extended from 0.962 to 1.395, a range of 0.433.

The results on individual prunes are summarized in table 1. Those on larger samples are shown in tables 3, 4, and 5. Tables 3 and 4, unlike tables 5 and 6, include data on count per pound, and the percentage of fruits found by visual tests to be off color, of normal external appearance, bloaters (porous flesh), or of bad flesh color.

TABLE 3

RELATION OF SPECIFIC GRAVITY AND WEIGHT PER VOLUME TO QUALITY OF PRUNES OF THE 1928 CROP

| District | Kind of sample | Number of samples | | Count per pound | External appearance: Fruits off color | External appearance: Fruits normal* | Weight per volume | | Specific gravity | Bloaters† | Bad flesh color |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | per cent | per cent | pounds | ounces | | per cent | per cent |
| A | Bin | 17 | Average | 75 | 19.2 | 54.3 | 40 | 5 | 1.231 | 20.1 | 21.0 |
| | | | Maximum | 124 | 36.8 | 79.0 | 42 | 3 | 1.301 | 52.2 | 40.8 |
| | | | Minimum | 48 | 10.2 | 33.3 | 38 | 10 | 1.174 | 6.5 | 8.3 |
| B | Bin | 11 | Average | 68 | 14.4 | 67.2 | 41 | 15 | 1.329 | 4.2 | 7.9 |
| | | | Maximum | 122 | 35.1 | 82.9 | 42 | 13 | 1.429 | 20.0 | 26.2 |
| | | | Minimum | 48 | 2.0 | 46.9 | 40 | 12 | 1.270 | 0.0 | 0.0 |
| | Growers' | 20 | Average | 60 | 2.7 | 39.7 | 41 | 15 | 1.324 | 35.5 | 10.5 |
| | | | Maximum | 87 | 35.1 | 74.9 | 43 | 15 | 1.369 | 84.7 | 26.4 |
| | | | Minimum | 38 | 0.0 | 0.0 | 40 | 3 | 1.174 | 0.0 | 0.0 |
| | All samples | 31 | Average | 63 | 6.9 | 49.5 | 41 | 15 | 1.324 | 24.3 | 9.8 |
| | | | Maximum | 122 | 35.1 | 82.9 | 43 | 15 | 1.429 | 84.7 | 26.4 |
| | | | Minimum | 38 | 0.0 | 0.0 | 40 | 3 | 1.174 | 0.0 | 0.0 |
| C | Bin | 12 | Average | 82 | 14.3 | 63.1 | 42 | 0 | 1.312 | 2.1 | 10.1 |
| | | | Maximum | 115 | 38.0 | 87.9 | 41 | 11 | 1.352 | 6.2 | 20.5 |
| | | | Minimum | 48 | 2.1 | 36.9 | 39 | 15 | 1.276 | 0.0 | 0.0 |
| | Growers' | 86 | Average | 67 | 8.3 | 33.4 | 42 | 8 | 1.301 | 32.3 | 25.6 |
| | | | Maximum | 132 | 73.5 | 86.9 | 44 | 6 | 1.385 | 79.2 | 66.2 |
| | | | Minimum | 32 | 0.0 | 0.0 | 39 | 15 | 1.132 | 0.0 | 0.0 |
| | All samples | 98 | Average | 68 | 9.0 | 37.1 | 42 | 4 | 1.302 | 28.5 | 23.7 |
| | | | Maximum | 132 | 73.5 | 87.9 | 44 | 6 | 1.385 | 79.2 | 66.2 |
| | | | Minimum | 32 | 0.0 | 0.0 | 39 | 15 | 1.132 | 0.0 | 0.0 |
| D | Bin | 11 | Average | 82 | 17.2 | 65.7 | 39 | 6 | 1.215 | 30.5 | 20.4 |
| | | | Maximum | 121 | 37.3 | 84.0 | 41 | 0 | 1.275 | 56.7 | 35.6 |
| | | | Minimum | 45 | 4.3 | 49.5 | 37 | 6 | 1.138 | 17.1 | 10.0 |
| | Growers' | 8 | Average | 76 | 17.2 | 54.4 | 40 | 2 | 1.214 | 53.6 | 25.3 |
| | | | Maximum | 115 | 75.1 | 84.5 | 42 | 2 | 1.271 | 91.5 | 47.9 |
| | | | Minimum | 59 | 0.0 | 26.4 | 37 | 14 | 1.136 | 12.2 | 2.7 |
| | All samples | 19 | Average | 80 | 17.2 | 61.0 | 39 | 12 | 1.215 | 40.2 | 22.5 |
| | | | Maximum | 121 | 75.1 | 84.5 | 42 | 2 | 1.275 | 91.5 | 47.9 |
| | | | Minimum | 45 | 0.0 | 26.4 | 37 | 6 | 1.136 | 12.2 | 2.7 |
| All districts | Bin | 51 | Average | 77 | 16.6 | 61.7 | 40 | 14 | 1.268 | 14.7 | 14.5 |
| | | | Maximum | 124 | 38.0 | 87.9 | 43 | 8 | 1.429 | 56.7 | 40.8 |
| | | | Minimum | 45 | 2.0 | 33.3 | 37 | 6 | 1.138 | 0.0 | 0.0 |
| | Growers' | 114 | Average | 66 | 8.0 | 37.0 | 41 | 11 | 1.324 | 35.3 | 23.6 |
| | | | Maximum | 132 | 75.1 | 86.9 | 44 | 6 | 1.385 | 91.5 | 66.2 |
| | | | Minimum | 32 | 0.0 | 0.0 | 37 | 14 | 1.132 | 0.0 | 0.0 |
| | All samples | 165 | Average | 70 | 10.6 | 43.9 | 41 | 3 | 1.290 | 28.3 | 20.7 |
| | | | Maximum | 132 | 75.1 | 87.9 | 44 | 6 | 1.429 | 91.5 | 66.2 |
| | | | Minimum | 32 | 0.0 | 0.0 | 37 | 6 | 1.132 | 0.0 | 0.0 |

* From this designation were excluded fruits defective in respects other than color.

† The term "bloaters" as used here includes not only the puffed, nearly spherical fruits called bloaters in the industry, but also fruits with a few large or many medium-sized air pockets and those with spongy or woody tissue of low specific gravity.

RELATION OF SPECIFIC GRAVITY AND WEIGHT PER VOLUME TO QUALITY OF PRUNES OF THE 1929 CROP

| District | Kind of sample | Number of samples | | Count per pound | External appearance: Fruits off color | External appearance: Fruits normal* | Weight per volume | | Specific gravity | Bloaters† | Bad flesh color |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | per cent | per cent | pounds | ounces | | per cent | per cent |
| A | Bin | 12 | Average | 80 | 13.5 | 45.4 | 41 | 6 | 1.292 | 15.5 | 15.4 |
| | | | Maximum | 113 | 29.2 | 60.4 | 42 | 8 | 1.377 | 45.3 | 31.3 |
| | | | Minimum | 47 | 0.0 | 31.9 | 40 | 8 | 1.242 | 2.9 | 0.0 |
| | Growers' | 45 | Average | 55 | 9.1 | 57.5 | 41 | 4 | 1.259 | 24.5 | 5.3 |
| | | | Maximum | 82 | 37.8 | 76.5 | 43 | 3 | 1.345 | 27.5 | 30.0 |
| | | | Minimum | 36 | 0.0 | 32.2 | 38 | 8 | 1.163 | 0.0 | 0.0 |
| | All samples | 57 | Average | 60 | 10.1 | 55.0 | 41 | 4 | 1.266 | 22.6 | 7.5 |
| | | | Maximum | 113 | 37.8 | 76.5 | 43 | 4 | 1.377 | 57.5 | 31.3 |
| | | | Minimum | 36 | 0.0 | 31.9 | 38 | 8 | 1.163 | 0.0 | 0.0 |
| B | Bin | 4 | Average | 77 | 10.8 | 52.1 | 42 | 10 | 1.295 | 5.9 | 2.7 |
| | | | Maximum | 99 | 18.6 | 58.5 | 43 | 3 | 1.332 | 11.0 | 6.9 |
| | | | Minimum | 53 | 5.9 | 41.2 | 42 | 3 | 1.252 | 1.9 | 0.0 |
| | Growers' | 41 | Average | 60 | 15.2 | 50.4 | 41 | 13 | 1.293 | 9.5 | 1.7 |
| | | | Maximum | 107 | 38.6 | 88.9 | 43 | 12 | 1.338 | 19.1 | 13.2 |
| | | | Minimum | 35 | 0.0 | 2.6 | 41 | 1 | 1.241 | 1.8 | 0.0 |
| | All samples | 45 | Average | 61 | 14.8 | 50.6 | 42 | 1 | 1.293 | 9.2 | 1.8 |
| | | | Maximum | 107 | 38.6 | 88.9 | 43 | 12 | 1.338 | 19.1 | 13.2 |
| | | | Minimum | 35 | 0.0 | 2.6 | 41 | 1 | 1.241 | 1.8 | 0.0 |
| C | Bin | 14 | Average | 81 | 10.2 | 50.4 | 43 | 0 | 1.304 | 4.3 | 6.1 |
| | | | Maximum | 134 | 21.8 | 57.5 | 45 | 12 | 1.345 | 10.2 | 18.3 |
| | | | Minimum | 49 | 0.0 | 41.4 | 41 | 12 | 1.228 | 0.0 | 0.0 |
| | Growers' | 25 | Average | 64 | 4.0 | 60.2 | 41 | 13† | 1.312 | 9.0 | 5.4 |
| | | | Maximum | 89 | 16.7 | 79.6 | .... | .... | 1 396 | 29.1 | 26.6 |
| | | | Minimum | 40 | 0.0 | 36.0 | .... | .... | 1.218 | 0.0 | 0.0 |
| | All Samples | 39 | Average | 70 | 7.2 | 56.7 | 42 | 13 | 1.308 | 7.3 | 5.6 |
| | | | Maximum | 134 | 21.8 | 79 6 | 45 | 12 | 1 396 | 29.1 | 26.6 |
| | | | Minimum | 40 | 0.0 | 36.0 | 41 | 12 | 1.218 | 0.0 | 0.0 |
| D | Bin | 15 | Average | 80 | 10.3 | 54.0 | 41 | 13 | 1.270 | 24.6 | 9.0 |
| | | | Maximum | 126 | 25.8 | 65.9 | 47 | 5 | 1.331 | 43.1 | 31.4 |
| | | | Minimum | 46 | 1.6 | 40.5 | 39 | 9 | 1 220 | 14.4 | 1.3 |
| | Growers' | 53 | Average | 72 | 9.5 | 49.4 | .... | .... | 1.248 | 30.1 | 10.1 |
| | | | Maximum | 101 | 26.8 | 75.2 | .... | .... | 1 302 | 62.9 | 30.5 |
| | | | Minimum | 35 | 0.0 | 20.6 | .... | .... | 1.122 | 13.0 | 0.0 |
| | All samples | 68 | Average | 73 | 9.7 | 50.7 | 42 | 3 | 1.252 | 28.9 | 9.8 |
| | | | Maximum | 126 | 26.8 | 75.2 | 47 | 5 | 1.331 | 62.9 | 31.4 |
| | | | Minimum | 35 | 0.0 | 20.6 | 39 | 9 | 1.122 | 13.0 | 0.0 |
| All districts | Bin | 45 | Average | 80 | 11.2 | 50.4 | 42 | 3 | 1.290 | 14.2 | 9.3 |
| | | | Maximum | 134 | 29.2 | 65.9 | 47 | 5 | 1.377 | 45.3 | 31.4 |
| | | | Minimum | 46 | 0.0 | 31.9 | 39 | 9 | 1.220 | 0.0 | 0.0 |
| | Growers' | 164 | Average | 65 | 9.4 | 53.5 | 41 | 8 | 1.272 | 20.2 | 6.0 |
| | | | Maximum | 107 | 38.6 | 88.9 | 43 | 12 | 1.396 | 62.9 | 30.5 |
| | | | Minimum | 35 | 0.0 | 2.6 | 38 | 8 | 1.122 | 0.0 | 0.0 |
| | All samples | 209 | Average | 68 | 9.8 | 52.8 | 41 | 13 | 1.275 | 18.9 | 6.7 |
| | | | Maximum | 134 | 38.6 | 88.9 | 47 | 5 | 1.396 | 62.9 | 31.4 |
| | | | Minimum | 35 | 0.0 | 2.6 | 38 | 8 | 1.122 | 0.0 | 0.0 |

* See first footnote, table 3. † See second footnote, table 3. ‡ Only one sample.

TABLE 5

RELATION OF SPECIFIC GRAVITY AND WEIGHT PER VOLUME TO QUALITY OF PRUNES OF THE 1930 CROP

| District | Number of samples | | Defects, external: Major* | Defects, external: Weighted† | Defects, external: Total‡ | Weight per volume | | Specific gravity |
|---|---|---|---|---|---|---|---|---|
| | | | per cent | per cent | per cent | pounds | ounces | |
| A | 23 | Average | 17.1 | 19.2 | 30.8 | 40 | 13 | 1.273 |
| | | Maximum | 42.4 | 43.7 | 60.0 | 42 | 15 | 1.338 |
| | | Minimum | 9.0 | 10.1 | 12.0 | 38 | 12 | 1.178 |
| B | 30 | Average | 11.8 | 14.5 | 27.6 | 41 | 14 | 1.290 |
| | | Maximum | 29.0 | 29.5 | 55.0 | 45 | 9 | 1.340 |
| | | Minimum | 3.0 | 5.4 | 9.0 | 38 | 15 | 1.228 |
| C | 21 | Average | 10.3 | 12.9 | 25.4 | 40 | 15 | 1.300 |
| | | Maximum | 19.4 | 21.8 | 40.0 | 42 | 14 | 1.347 |
| | | Minimum | 4.0 | 6.2 | 17.0 | 39 | 9 | 1.252 |
| All | 74 | Average | 13.0 | 15.7 | 28.0 | 41 | 7 | 1.288 |
| | | Maximum | 42.4 | 43.7 | 60.0 | 45 | 9 | 1.347 |
| | | Minimum | 3.0 | 5.4 | 9.0 | 38 | 12 | 1.228 |

* Percentage of fruits with important defects only.

† Minor defects included but given reduced weight in the percentages.

‡ Both major and minor defects included and given the same weight in the percentage.

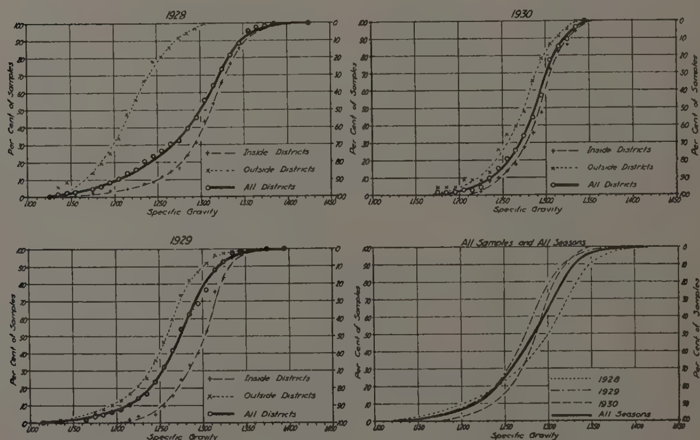


Fig. 7. The distribution curves of specific gravity among samples of the 1928, 1929, and 1930 crops.

The proportion of samples found to be of various specific gravities in the range observed is shown graphically in figure 7. It will be noted that the average specific gravity of the samples from the inside districts (B and C) was higher for all three seasons than of those from the outside districts (A and D). There was, however, considerable overlapping of values. Thus, as shown in figure 7, 50 per cent of all samples in 1930 had specific gravities below 1.29; only 40 per cent of the samples from the inside districts had specific gravities below this value, while 60 per cent of the samples from the outside district were below 1.29 in specific gravity.

The average and range of specific gravity of samples from all the principal districts are shown for the three years in tables 3, 4, and 5. It will be seen that seasonal variations occurred, but these were not large, and the average for each district remained in a range that is characteristic of the district. Also, the values in districts A and D were similar to each other but lower than those of districts B and C, which were also similar to each other.

*Effect of Moisture Content on Specific Gravity.*—In order to determine the effect of change in the moisture content upon the specific gravity of prunes, two samples each of about 20 per cent moisture content were tested, then dehydrated to moisture contents of about 10 per cent. Increases of 0.016 and 0.045 in the specific gravity appeared when the samples were again tested, using the same fruits. Using the observed specific gravities and moisture contents, the calculated changes in specific gravity were approximately 0.037 and 0.033, respectively. In the first case the specific gravity change observed was 0.021 less than that calculated, indicating probably that the air pockets of the fruit became relatively larger during drying. In the second case the specific gravity change observed was 0.012 more than that calculated, indicating that the air pockets became relatively smaller during drying. The fact that such small changes occurred as a result of such large changes in moisture content was taken to indicate that variations in moisture content did not impair the usefulness of the method. The changes in moisture content in the experiment were approximately twice the normal range of moisture content of prunes delivered to packing houses. Also, since the specific gravity decreases as the moisture content increases, any changes in the specific gravity from this cause is in the right direction; the value of the fruit is less at higher moisture content.

*Effect of Temperature on Specific Gravity.*—A similar study was made of the effect of temperature upon the specific gravity. Ten

samples were tested at 70° F, and again after the temperature had been adjusted to 32° F. The change in temperature had but slight effect upon the specific gravity, the average increase in the reading being about 0.01 for this difference in temperature. Since this variation in temperature was as great as any to be expected in commercial practice, it was concluded that the effect of temperature on specific gravity could be ignored.

*Observations on Weight per Volume.*—The weight per volume test was made upon all samples of sufficient size. The results are summarized with other data in tables 3, 4, and 5. The W/V value, like the specific gravity, was found to increase with increase in the proportion of fruits having solid texture and good color in the flesh. The extreme range of W/V values found in all the samples studied for the three seasons was from 37 pounds 6 ounces to 47 pounds 2 ounces, a difference of 9 pounds 12 ounces.

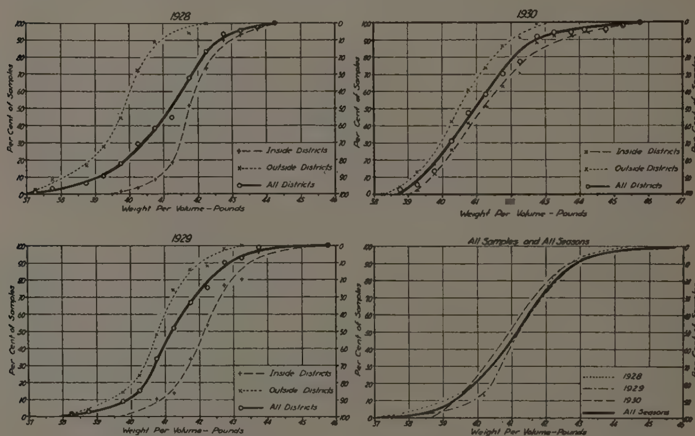


Fig. 8. The distribution curves of weight per volume among samples of the 1928, 1929, and 1930 crops.

The average W/V values were higher in the inside districts B and C than in the outside districts A and D. The proportion of samples occurring at different weights per volume is shown in figure 8. It will be noted that the overlapping of values among samples from the different districts is very much like that in figure 7. Thus, in 1930, 50 per cent of all samples studied showed a weight per volume of less than 41 pounds. Of the samples from the inside districts, only

45 per cent tested less than 41 pounds, while 67 per cent of the samples from outside districts had a W/V value of less than 41.

The influence of moisture content upon the W/V value was found to be slight but less regular than upon the specific gravity. Of three wet samples tested before and after further drying, two gained 2 and 3 ounces, respectively, while one lost 8 ounces in weight per volume during drying to the lower moisture content.

*Effect of Temperature on W/V Value.*—Temperature had a much more pronounced effect upon weight per volume than upon specific gravity. Three samples tested at 70° and at 32° F increased by 1 pound 7 ounces, 1 pound 11 ounces, and 1 pound 12 ounces, respectively, in W/V value in changing from the higher to the lower temperature.

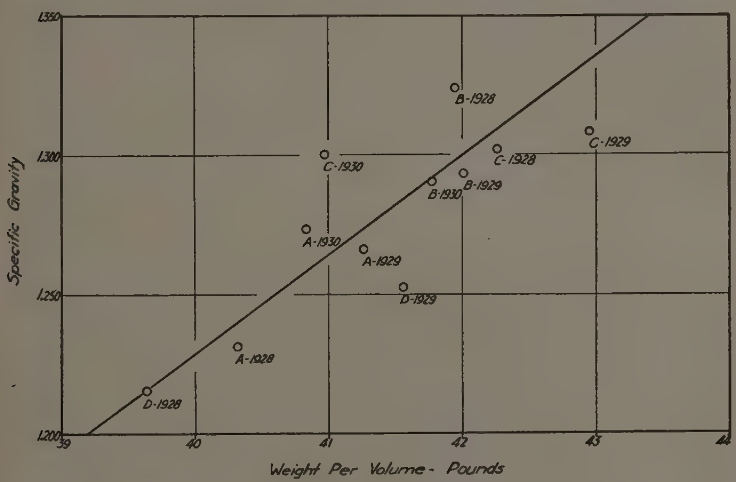


Fig. 9. Relation between average weight per volume and specific gravity of prunes for different localities and different seasons.

These differences were too great to appear to be the result of contraction of the fruit. It was noted that the fruit was less sticky at 32° than at 70° F. The higher W/V value at the lower temperature was attributed to changes of viscosity of the sirup on the surface of the fruit. This change could be assumed to affect the settling of the fruit in the container.

To determine the effect of stickiness a sample of very sticky fruit was subjected to the W/V test. It was then dipped in small portions in water at about 140° F and quickly dried first with towels and then for a few minutes in a dehydrater. Such treatment could have little

or no effect on the moisture content. After the fruit had been restored to room temperature it was tested again. It was no longer sticky. The W/V value before washing was 42 pounds 11 ounces; that after washing was 44 pounds 1 ounce. It appeared, therefore, that the removal of the stickiness without other change in the character of the fruit resulted in better settling in the test can, and thus an increased weight per volume. This was thought to confirm the hypothesis that changes in weight per volume resulting from changes in temperature were principally due to the effect of temperature upon the stickiness of the fruit.

This factor of stickiness is thought to account for the fact that the association between specific gravity and weight per volume of the samples was not closer. A study of tables 3, 4, and 5 shows that these tests did not always vary in the same direction, even among the average values, and this is shown graphically in figure 9. The degree of conformity, if individual determinations were compared, was much less. Yet there can be no doubt that both the specific gravity and the weight per volume are affected directly by the porosity of the flesh of the fruit.

## DISCUSSION OF RESULTS

Two tests were developed for measuring the quality of the flesh. The color of the flesh was found to be closely associated with the texture, and the tests were based upon the latter, since it can be more easily and accurately measured. Both tests, namely, specific gravity and weight per volume, chiefly reflect the fact that increasing porosity of the flesh decreases the weight of a prune of given size or volume. The specific gravity test appeared to be least affected by interfering characteristics, chief of which was the stickiness of the fruit. Since stickiness was influenced by temperature, misleading results may be obtained by the weight per volume test unless it is made at an approximately constant temperature. Tests on sticky fruit would probably be affected more than would those of fruit relatively free of stickiness. For this reason testing fruit at different temperatures and applying a temperature correction would seem inadvisable and inaccurate. Therefore, the specific gravity test was thought to reflect more exactly the texture of the flesh if the inconvenience of temperature adjustment were to be avoided. On the other hand, the weight per volume test had the advantages of using larger samples, of not affecting the immediate usefulness of the fruit

in the sample tested, and of discriminating against sticky fruit. In view of these facts the relative usefulness of the two tests could be determined only by practical considerations not studied by us, although, as a strict indication of texture alone, the specific gravity test was considered more reliable.

Within each of the four principal prune-producing districts from which samples were studied, the annual variations of average specific gravity and W/V value observed were not great with respect to the extent of the range of values found among individual samples. This is apparent from tables 3, 4, and 5 and figures 7 and 8. It seems to indicate that allowances for seasonal variation would not be necessary, and that permanent or semi-permanent standards could be established. From this point of view the nature of the test described herein, together with the test for size, skin condition, and moisture content, to be discussed by the authors in another paper, would make possible a system of grading having certain distinct improvements over the one now in commercial use. A system of the latter type, based as it is on rather indefinite specifications and dependent on trained individual judgment, is capable of classifying a crop into but few grades. This is not a natural classification, for it is obvious that fruit from different orchards and growers must vary through a continuous range of quality from the best to the poorest. A large number of deliveries, therefore, must vary by but the most minute degree, which the judgment of different inspectors is manifestly incapable of recognizing. From this fact arises the principal inherent objection to the commercial system now in use and the principal advantage of a specific, mechanical system. Through use of the latter the crop may be graded in a much larger number of quality classifications more closely related to the slight changes of quality naturally occurring.

## SUMMARY AND CONCLUSIONS

Examination of a large number of samples of California French prunes chosen to represent the principal prune-growing sections of the state over a period of three years showed that:

Flesh texture and color are correlated with, and can thus be measured by, the specific gravity.

Flesh texture and color are also measured by weight per volume. While this test is affected by stickiness of the fruit, this theoretical objection to the test may be a practical advantage since it penalizes abnormally sticky fruit.

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